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Measuring Cost Efficiency and Its Determinants in Ethiopian Commercial Banks: A Stochastic Frontier Analysis

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Abstract

The study analysed the measurement of cost efficiency and its determinants in Ethiopian Commercial Banks by *using a balanced sample of 14 private commercial banks over the period 2010-2020 by employing stochastic frontier approach and Tobit model. The study found that banks' efficiency level has witnessed a wide variation across various bank groupings and fluctuated over the study period. The study also found that, the cost efficiency of the state-owned commercial banks and private commercial banks over the study period is 0.75 and 0.83 respectively. The findings show that banks specific factors of return on equity, and intermediation ratio have a statistically significant and positive effect on the cost-efficiency of commercial banks in Ethiopia. However, branch network has a statistically significant and negative effect on the bank's cost-efficiency. Nevertheless, bank size, return on asset, capital adequacy ratio, real gross domestic products and age of banks are not statistically significant. Thus, commercial banks can improve their cost efficiency by way of improving their return on equity, and intermediation ratio. Commercial banks should minimize the use of input resources while maintaining the same level of output. By improving the handling of operating expenses, general expense, interest expense, and boosting loan providing they can improve their cost-efficiency.*

Keywords: *Cost efficiency, Ethiopian commercial banks, Stochastic Frontier Analysis.*

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Introduction

Commercial banks perform a variety of banking functions such as accepting deposits, advancing loans, financing foreign trade, agency functions, and miscellaneous services to customers. Thus, commercial banks can help in overcoming these obstacles and promoting economic development by granting loans to agriculture, trade, and industry, by helping in the formation of physical and human capital and by following the monetary policy of the country. Furthermore, a well-organized, competitive, and comprehensive financial system is important for improving agricultural production, to expand micro and small enterprises, to reduce unemployment, to improve the growth and development of a nation. Efficiency is producing the right goods/services of the right quality at the right cost. It is the success with which a firm uses its resources to produce the output of a given quality (Farrell, 1957).

Efficiency is producing the right goods/services of the right quality at the right cost. It is the success with which a firm uses its resources to produce the output of a given quality (Farrell, 1957). Thus, the study examined the efficiency level and variations among Ethiopian banks and point out the major factors impacting the efficiency of banks. It has used a long period data (2010-2020) and applies a SFA approach to measure cost efficiency. Lelissa and Mohammed (2016) studied the about the measurement of the cost efficiency of Ethiopian banks by using DEA over the period 1999-2015. Except for an empirical study that was investigated by Emishaw (2016), there is no other empirical study that investigated the determinant of private commercial banks operating in Ethiopia since to exist. This paper attempted to make empirical evaluations on the determinant of the cost efficiency of commercial banks operating in Ethiopia. Nevertheless, it falls to cover the major determinant of cost efficiency such as Liquidity, equity multiplier, capital, age, and branch network of private commercial banks.

However, most of the above previous studies limited their investigation only for cost efficiency and neglect the causes of cost inefficiency; their study is not a recent period and compares the efficiency of banks based on their ownership. Currently, there are 16 private commercial banks in Ethiopia and each bank tries to be unique as compared to its competitors to achieve a higher market share. Therefore, it becomes imperative to determine the cost efficiency level of private banks in Ethiopia and determine the factors that affect the bank efficiency level. Costs have also been

increasing as a result of increased capitalization directed towards the strategic expansion of banks through their branches countrywide (NBE 2017/18). The increased costs are attributed to the rising employee and interest expenses amongst other factors.

The report of NBE (2022) indicates that there are one public and nineteen private commercial banks operating in the country making, a total of 20 commercial banks in the country. Thus, this study attempts to find out the measurement for cost efficiency and its determinants in Ethiopian commercial banks by employing a Fourier-flexible functional stochastic cost frontier approach and using 14 private commercial banks operating in the country that have 6 years of data and,. The study fills the gap in the existing literature by including new variables (Liquidity, equity multiplier, capital, age and branch network) and examining the cost-efficiency of private commercial banks in a recent period of time.

The general objective of this study was analyzing major determinants of the cost efficiency of commercial banks operating in Ethiopia. Specifically, it focused on the factors that can lead to the cost efficiency of private commercial banks operating in Ethiopia. It examines the parameters of cost-efficiency frontier, and based on the result, to draw some policy comments that may be useful in designing effective policies for enhancing cost-efficiency to achieve full cost-efficient banks thereby minimize cost objectives of the study area in particular and the country in general. The research questions, which are addressed by this study using different approaches are: What are the principal factors that determine cost-efficiency of private commercial banks operating in Ethiopia? Are private commercial banks are cost-efficient during the study period? Is there a significant variation in cost efficiency among the sample banks across during the study?

Review of Literature

Theoretical Literature

Technical efficiency is most frequently associated with the role of management in the production process. For instance, Liebenstein (1966) has argued that firms may fail to produce on the outer boundary of their production surface due to the structure of preferences of managers and workers, giving rise to variations in the level of "X efficiency''. The level of technical efficiency of a particular firm is characterized by the relationship between observed production and some ideal or potential production. The measurement of a firm's specific technical efficiency is based upon deviations of observed output from the best production of the efficient frontier. If a firm's actual production point lies on the frontier, it is perfectly efficient. If it lies below the frontiers, then it is technically inefficient.

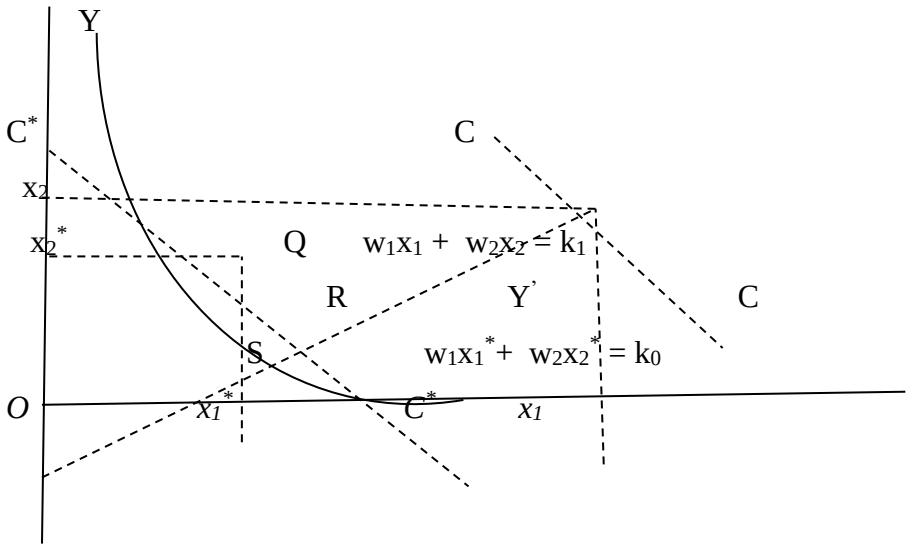
Allocative efficiency refers to the ability of a firm to choose the optimal combination of inputs given input prices (Farrell, 1957). If a firm realizes both technical and allocative efficiency, it is then cost-efficient (overall efficient). Allocative efficiency measures the skills in achieving the best combination of inputs by taking in to account their relative prices or produces the right mix of outputs given the set of prices (Kumbhaker and Hevell, 2000). It reflects the capability of a firm to utilize input in optimal proportion, given their respective prices and the production technology. In other words, allocative efficiency refers to whether inputs for a given level of output and set of input prices are chosen to minimize the cost of production; assuming that the firm being examined is already fully technically efficient.

During his seminary work, Farrell (1957) proposed a method of measuring productive efficiency. It used an efficient isoquant estimated as part of the convex hull of observed points. He assumed that the production function was homothetic. A homothetic function is a monotonic transformation of a homogeneous function in which the marginal rate of technical substitution is constant along a ray drawn from the origin (Varian, 1993). Using Varian (1993) argument of the homothetic function, to illustrate this analogy let the production function f (X1, X2) be homogeneous of the first degree in X1 and X2. Assuming that the iso-quant of this homogenous production function is an efficient isoquant, an increasing monotonic transformation of a homogenous production function yields a homothetic production function in F (X) = g [f (X1, X2)]. Where, g represents

the strictly increasing monotonic transformation. A series of homothetic isoquants can be derived from the original (efficient) isoquant by appropriate scaling up. Therefore, a proportional increase or decrease of all inputs does not affect the marginal rate of technical substitution along the isoquants. A comparison between the efficient isoquant and any other isoquant for a given output level would indicate a departure from a full efficiency level. The efficiency analysis carried out by Farrell (1957) for a single output and two inputs case in a unit iso-quant diagram as shown below:

Figure 1

Technical, Allocative and Cost Efficiency



Source: Cooper et al. (2007, p.258)

The technological set was fully described by the unit isoquant YY' that captured the combination of inputs (x_1, x_2) by which a given firm could produce a certain output when it is perfectly efficient. Therefore, YY' showed the minimum combination of inputs that were needed to produce a unit of output. Under this framework, every combination of inputs along an isoquant was considered as technically efficient while any point above and to the right of it, for example, point P was defined as a technically inefficient point. Here it was argued that the producer used an input combination that was more than enough to produce a unit of output. Hence, the distance RP along the OP line was considered to measure the technical inefficiency of a producer located at point P. The distance RP thus represents the amount by which all inputs can be reduced without decreasing the amount

of output. Cooper et al. (2007) argue that geometrically the technical inefficiency level associated with package P can be expressed by the ratio RP/OP and, therefore, the technical efficiency (TE) of the producer under analysis is given be the ratio OR/OP. It takes a value of 0 and 1. A value of 1 implies that the firm is fully efficient.

Therefore, allocative efficiency can also be derived from the unit isoquant plotted in figure 1. Given that the market prices of inputs are (w_1, w_2), the isocost line CC through P is associated with $w_1x_1 + w_2x_2 = k_1$ and the slope of this line reflect the input price ratio. However, moving the line parallel until it is tangential to the isoquant at point Q can further reduce this cost. The coordinates of CC then give: $w_1x^*_1 + w_2x^*_2 = k_0$, achieving the minimal cost at the determined output level. The relative distance between S and R can be used to obtain the ratio OS/OR. The above ratio with respect to the least cost combination of inputs given by point Q, indicates the cost reduction that a producer would be able to achieve if it is moved from a technically but not allocatively efficient input combination (R) to both a technically and allocatively efficient point (Q). Thus, the allocative efficiency of the producer is given by the ratio OS/OR. Cooper et al. (2007) further argue that there is another measure of cost efficiency or economic efficiency. It is represented by the ratio of minimum cost (wx^*) to actual cost (wx_0) i.e. $wx^*/wx_0 = OS/OP$. A cost efficient firm will choose its inputs and mixes according to their prices so as to minimize the total costs. Cost inefficiency can arise from different sources. One is the deficiency in application of technology (i.e. technical inefficiency) and another one is the sub-optimal allocation of resources(allocative inefficiency). Therefore, the total overall cost efficiency can be presented as the product of technical efficiency and allocative efficiency. Thus, OS/OR * OR/OP = OS/OP.

Concept of Cost Efficiency

The concept of efficiency was derived from the microeconomic theory of the firm. The Neo-Classical theory mainly concentrates on the efficient allocation and utilization of resources in the production process. The conventional Neo-Classical theory treats the firm as an organization that transforms resources into consumable goods. This transformation of inputs into output is described by a production function or production possibility set.

Lovell (2000) stated: *Efficiency represents the degree of success which producers achieve in allocating the available inputs and the outputs they produce, in order to achieve their goals and*

to attain a high degree of efficiency in cost, revenue, or profit. Efficiency is the ability of a decision-making unit to obtain the maximum output from a set of inputs (output orientation) or to produce an output using the lowest possible amount of inputs (input orientation).

The cost-efficiency of banks is a key indicator that provides valuable insight to researchers and policymakers about the functioning of the financial intermediation process, as well as, the overall performance of the entire financial system. Efficiency is a key concept for financial institutions. Efficiency is measured concerning an organization's objective; it can be measured to maximization of output, maximization of profits, or minimization of costs (Mester, 2009).

Lovell, (2000) efficiency represents the degree of success in which producers achieve in allocating the available inputs and outputs they produce to achieve their goals. The concept has the economic foundation for analyzing the efficiency of financial institutions because it is based on economic optimization with market prices and competition, rather than being based solely on the use of technology (Berger and Mester, 2008).

Efficiency Measures/Approaches

Technically, there are two approaches to measure the efficiency of banks i.e. parametric and non-parametric. Stochastic Frontier Approach (SFA), Thick Frontier Approach (TFA) and Distribution Free Approach (DFA) are classified under parametric approach and Data Envelopment Analysis (DEA) and Free Disposal Hull (FDH) are under non-parametric approach (Berger and Mester, 2008).

DFA specifies a functional form for the cost function as does SFA and TFA, but DFA separates inefficiencies from random error in a different way. It does not impose a specific shape on the distribution of efficiency (as does SFA), nor does it impose that deviations within one group of firms are all random error and deviations between groups are all inefficiencies (as does TFA). Instead, DFA assumes that there is a "core" efficiency or average efficiency for each firm that is constant over time, while random error tends to average out over time (Schmidt and Sickles 1984, Berger 1993).

TFA uses the same functional form for the frontier cost fiction as SFA but is based on a regression that is estimated using only the ostensibly best performers in the data set those in the lowest average cost quartile for their size class. Parameter estimates from this estimation are then used to obtain estimates of best-practice cost for all of the firms in the data set (Berger and Humphrey 1991). Banks in the lowest average cost quartile are assumed to have above-average efficiency and to form a "thick frontier." As it is usually implemented, TFA assumes that deviations from predicted performance values within the highest and lowest performance quartiles of firms represent random error, while deviations in predicted performance between the highest and lowest average-cost quartiles represent only inefficiencies (a special case of composed error) plus exogenous differences in the regressors. Measured inefficiencies thus are embedded in the difference in predicted costs between the lowest and highest cost quartiles. This difference may occur either in the intercepts or in the slope parameters. In most applications, TFA gives an estimate of efficiency differences between the best and worst quartile to indicate the general level of overall efficiency but does not provide point estimates of efficiency for all individual firms.

The major weakness of DEA as compared especially to the SFA is the fact that it does assume no random error such as measurement error (Raphael, 2012). Nonetheless, DEA does not require a prior specification about the underlying technology and it can accommodate multiple inputs and outputs (Raphael, 2013). As a result, it has got preference in the analysis of the technical efficiency of DMUs particularly banks and financial institutions. DEA involves the use of linear programming to construct a non-parametric piece-wise frontier over the data (Repkova, 2015).

The DEA approach decomposes cost (input saving) into technical efficiency and allocative efficiency as well as scale efficiency, interested in the concept of economic efficiency. DEA does not require the explicit specification of the form of the underlying production relationship (Berger &Humphrey, 1997). SFA was developed by Aigner, Lovell & Schmidt (1977). SFA mainly with analysis of cost efficiency: Concept of efficiency, Estimation, and Identification of sources of inefficiency (Lovell, 2000).

SFA employs a composed error model in which inefficiencies are assumed to follow an asymmetric distribution, usually the half-normal, while random errors are assumed to follow a symmetric distribution, usually the standard normal (Aigner, Lovell, and Schmidt 1977). That is,

the error term horn the cost function is given by $\varepsilon = v + u$, where $v > 0$ represents inefficiency and follows a half-normal distribution, and u represents random error and behaves according to a normal distribution. The reasoning is that inefficiencies cannot subtract from costs, and so must be drawn horn a truncated distribution, whereas random error can both add and subtract costs, and so maybe drawn from a symmetric distribution. Both the inefficiencies v and the random errors u are assumed to be orthogonal to the input prices, output quantities, and my other cost function regressors specified. The efficiency of each firm is based on the conditional mean (or mode) of inefficiency term v, given the residual which is an estimate of the composed error (ε).

Generally, the parametric approaches have the advantage of using strong assumptions concerning the form of the efficient frontier and therefore involve a certain economic behavior. In addition, it allows for tests of economic hypothesis concerning the goodness of fit of the model. Therefore, the study's conceptual framework is based on the SFA approach, which is justifiable from the most important advantages of the SFA methodology.

Empirical Literature

Measuring Cost efficiency of commercial banks

Vitali and Fontani (2014) examine the cost efficiency of Italian commercial banks by using SFA approach for the period 1993-2004. This study found that structural changes in financial conditions and slackening in the potential output growth heavily affected the competitive environment of the Italian banking system. The result found that the mean value of inefficiency is slightly higher than other studies suggest and close to 20%, mainly because of improper use of scale factors and of input congestion.

Sana et al., (2015) use a SFA and intermediation approach to measuring to evaluate the cost efficiency of 26 commercial banks in Pakistan over the period 2005 to 2013. They use deposits, labor, fixed assets, capital, other expenses as inputs; while loans and advances and other investments were used as outputs. The result shows that the cost function reveals Pakistan's banking sector has a high margin of improvement in its cost efficiency either by maximizing the output through diversification or reduction in the price of input resources. They also found that the

banks could reduce their cost inefficiency by 33.52 % on average or in other words they could have used only 66.48% on average of their resources (inputs) to produce the same level of outputs. Ally and Patel (2014) use DEA to evaluate the efficiency of commercial banks operating in Tanzania during the year 2006 to 2013. The study reveals that banks operate at 95.9% level of efficiency i.e. inputs could be reduced by 4.1% without sacrificing output if all banks were efficient as benchmark banks identified by DEA.

Berger and Mester (1997), explored the relationship between the age of the bank and efficiency to investigate the theory that says bank production might involve (learning by doing) (Mester 1996). Their result, however, showed a very small coefficient on the contribution of age to efficiency. They found that the cost efficiency estimates do not vary much across asset sizes. They suggest that cost and profit efficiency results together seem to imply that, as banks grow larger, they equally able to control costs, but it become harder to efficiently create revenues. This is consistent with conventional wisdom and the historical facts that small banks typically have a higher profitability ratio. It also helps to explain the lack of a positive correction between cost efficiency and profit efficiency.

Ferrier and Lovell (1990) applied both the Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) to measure the cost efficiency level of USA banks. They conducted an explicit comparison between the two methods and discussed the results obtained. They analyzed the cost structure of 575 banks and concluded that the two methods generally drew similar conclusions on the average level of cost efficiency.

Lyocsa and Pancurova (2013) use DEA to estimate the cost efficiency and their determinants for a sample of 11central and Eastern European countries over the 2005-2008 periods. They found evidence that the size and financial capitalization of banks are positively associated with cost efficiency but the loans to asset ratio were negatively associated with cost efficiency.

Zhao, H., & Kang, S. (2015). measure cost efficiencies of 18 Chinese commercial banks, divided into the state-owned banks and the joint-stock banks, by the trans log cost function based on stochastic frontier analysis (SFA). They found that there is an upward trend in the overall mean of cost efficiencies of both the state-owned banks and the joint-stock banks, and the cost efficiencies of the state-owned banks has improved greatly. Das and Roy (2015) use DEA to assess the cost

and revenue efficiency of State Cooperative Banks in India. The results show that though the banks are not fully efficient in all respects, but they maintained productive capacity in the same order as the averages in All India SCBs and all are better at utilizing inputs more than generating optimal outputs.

Determinant of commercial bank's cost efficiency

Kariuki (2011) uses SFA to examine determinants of the cost efficiency level of commercial banks in Kenya over the period from 2002-2011. The findings of the study showed that the average cost efficiency level of commercial banks in Kenya over the period from 2002-2011 is around 99.25%. This study found that the efficiency improvement is in response to the concerted efforts of cutting down on the operating costs by the management of banks, explained by the various strategies adopted. This study also found both the asset concentration and government securities coefficients are observed to be positive and insignificant. Nevertheless, both the inflation and loans coefficients are observed to be positive and significant.

Regarding African studies, Kablan (2010) uses SFA to assess the determinants of banking system efficiency and financial development in Sub Saharan Africa over the period 2007 to 2009. Sub Saharan African banks found to be generally cost efficient, however non-performing loans undermine efficiency. The study found that banks are estimated to be efficient at 76 percent given their strategy of transformation of the deposits they collect into short-term loans generally and long-term loans to big companies. The result shows that in order to improve efficiency there should be an improvement in the regulatory and credit environment.

In Ethiopia, Tadele (2016) examined the determinants of commercial banks' efficiency in Ethiopia over the period 2003–2012 using DEA. The study results showed that deposit and liquidity are found to have a positive and significant effect on bank efficiency, while profitability, loan quality, expenses, bank size, and diversification did not have a significant effect on bank efficiency.

Lelissa Mohammed (2016) measure the cost efficiency of Ethiopian Banks during the period of 1999-2015 by using DEA and intermediation approach. The study uses Tobit regression model to look determinant of cost efficiency. They use deposit, branch and fixed asset as input while loan and advances and other earning as output. The study found that the state banks efficiency has been

consistently on the efficiency frontier reflecting the high dominance of the banks in the Ethiopian banking system and small private banks efficiency is growing overtime while the middle size private banks are facing difficult to improve their level of efficiency. In addition, they found that deposit growth rate, loan size and earning asset growth are positively and significantly related to efficiencies while branch size and fixed asset growth rate are negatively and insignificantly related to efficiencies.

Rao and Lakew (2012), studied to examine the relationship between cost efficiency and ownership structure of commercial banks in Ethiopia using DEA over the period 2000-2009. They use Tobit regression model to look into the major variables that affect the cost efficiency of the commercial banks in Ethiopia. They found that the average cost efficiency of state-owned commercial banks over the period 2000-2009 is 0.69 while the private commercial banks are 0.74. The aggregate cost efficiency of Ethiopian commercial banks is found to be 0.73. The study conclude that the state-owned commercial banks are less cost efficient than the private commercial banks. According to the study's evidence, ownership structure has no significance influence on the cost efficiency of commercial banks in Ethiopia. The study also identified that bank size, loan loss reserve to total assets, market share, market concentration, capital adequacy, and return on average assets as the key factors that influence the cost efficiency of the commercial banks.

Emishaw (2016) examines the determinants cost-efficiency of commercial banks in Ethiopia over the period 2000-2013 by employing SFA. The results show that Ethiopian banks are on average inefficient in the order of 7.5 %, indicating that mismanagement of resources remains a problem to better cost performance. In addition, the study identified returns on assets, returns on equities and intermediation ratio are positively and significantly related to bank efficiency while there was no significant relationship found between bank size and bank efficiency and capital adequacy ratio has a negative impact on efficiency. To sum up**,** the literature reviewed indicated that there is no clear consensus on the specification of banking outputs in spite of a large number of studies on the cost efficiency of the banking sector.

Research Methodology

Source and method of data collection

The data used for this study will be gathering from secondary sources data. Secondary sources of data will be obtained from the annual report of the National Bank of Ethiopia (NBE) and the annual reports for each respective bank. This study uses balanced panel data of 14 commercial banks operating in Ethiopia for the period 2010-2020.

Sample Size

The report of NBE (2022) indicates that there are 1 public and 19 private commercial banks operating in the country making, a total of 20 commercial banks in the country. Among these, 13 commercial banks (a total of 20 commercial banks) are included in the study period 2010-2020. Because other private banks are too young, they have not organized data on the required variables over the study period.

Method of Data Analysis

The data will be analysed using appropriate descriptive statistics and parametric techniques. Simple descriptive statistics will be used to present data in the form of a table, percentage, frequency, variance, standard deviation and mean. This study will use the parametric technique of SFA due to its convenience and ease of application in the data econometric analysis. The SFA approach is chosen over the DEA approach because it allows for the use of simultaneous estimation of both the cost function and the inefficiency model, a feature not supported by the DEA linear programming approach. Besides, the SFA is superior to the DEA technique due to the fact that it better deals with the problem of statistical noise (i.e. unexplained random variation of a sample) with the use of panel data, thus allowing for the inclusion of additional information from the multiple periods into the estimation.

This study applies the intermediation approach in determining the banking efficiency level. The intermediation approach is superior to the production approach because the former is characterized by fewer data problems than the latter (Rao, 2002). The intermediation approach is thus considered to be effective in evaluating the entire banking industry, as it is inclusive of the interest expenses that account for 50-60 percent of the total costs in banks. Moreover, the study made an attempt to

explore the key factors that affect the cost efficiency of the commercial banks using the Tobit model.

Specification of the Stochastic Cost Frontier Model

The stochastic frontier analysis literature relaxes the neoclassical full efficiency assumption by allowing the productive units to be inefficient. Aigner et.al. (1977) and Meeusen and Broeck (1977) exemplify earlier studies of stochastic frontier models that aim to measure efficiencies of productive units. A common feature of stochastic frontier analysis is that they assume a composed error term where the first component is the usual two-sided error and the second component is a one-sided (non-negative) error term, which represents inefficiency. A variety of distributions is proposed for the one-sided error component including the half-normal (Aigner et.al., 1977) the exponential (Meeusen and Broeck 1977) the truncated normal (Stevenson, 1980), the gamma (Greene, 2002) and doubly truncated normal distributions (Almanidis, 2014).

In this section, the researcher specifies the model we used to measure cost (in) efficiency of individual commercial banks operating in Ethiopia. It is also customary to use the Fourier-flexible functional form instead of the trans log form. The Fourier- flexible functional form includes a standard trans log plus Fourier trigonometric terms. These additional variables can make the approximating function closer to the true path of the data wherever it is most needed. It is also believed that a good fit of the data for the estimated efficient frontier is important in estimating efficiency because inefficiencies are measured as deviations from this frontier. It simultaneously measures the degree of inefficiency both from the input and output standpoint, handling multiple outputs while preserving the typical properties of symmetry and curvature of the frontier. Unlike Cobb-Douglas, a translog function allows adequate handling of multiple outputs, while preserving the typical properties of symmetry and curvature of the frontier. Furthermore, increasing distortions of efficiency levels could originate from excessive simplification of the production processes, if significant factors are excluded from the analysis.

According to Berger and Mester (1997) and Shen and Jones (2008), cost efficiency provides a measure of how close a bank's actual cost is to what a best practice institution's cost would be for producing the same output bundles under the same conditions. As indicated by Berger and Mester

(1997), cost efficiency shows how close a firm/ bank costs are to the costs of efficient firm/bank. The bank positioned on the frontier, produce more output under the same conditions. This can be derived from a cost function, as shown below:

$$C = C(w, y, v, u) \quad \ldots\ldots (1)$$

where c measures the cost, w is the vector input price, y is the output quantities vector, v is the normal random error and u stand for an inefficiency factor (technical, cost or allocative according to function used), due to which the costs may increase above the best practice level.

The measure is derived from a cost function in which total cost depends on the prices of inputs (W), the output quantities (Y) and an error term (ε). Thus the general form for the stochastic cost frontier function specified as follows:

$$Cit = f(W_{it}, Y_{it}; \beta) + \varepsilon_{it} \quad \ldots\ldots (2)$$

Where C measures total cost, X is a vector of input prices, Y is a vector of output quantities, β's are parameters to be estimated.

The error term further decomposed into

$$\varepsilon it = vit + \mu it$$

The other component μ_{it} captures the inefficiency term which follows a half-normal distribution. Furthermore, μ_{it} and V_{it} are independently and identically distributed. The inefficiency component, (μ_{it}) is assumed to be a function of a set of bank specific variables (Z_{it}) that may affect performance, a vector of coefficients to be estimated (θ) and random error (W_{it}).

$$\mu_{it} = Z_{it}\theta + W_{it} \quad \ldots\ldots (3)$$

Where, the random variable W_{it}has a half normal distribution with zero mean and variance $\sigma^2\mu$. Consequently, according to Kumbhakar and Lovell (2000) the estimation of banks relative efficiency using panel data is obtained by estimating a translog cost function of the general form as follows:

$$\ln C_{it} = \ln C_{it}\,(Y_{it}, W_{it}; \beta) + \varepsilon_{it} \quad \text{.....(4)}$$

Where $\varepsilon_{it} = V_{it} + \mu_{it}$ for every bank i = 1,.., N; C_{it} is total cost of bank i, Y_{it} is outputs' vector of bank i, W_{it} is inputs' vector of bank i, Z_{it} is bank specific variables, β is vectors of parameters to be estimated, μ_{it} is the measure of inefficiency of bank i and is determined by a set of bank specific variables.

Nevertheless, Berger and Mester (1997) found that both the translog and the Fourier-flexible functional forms yielded essentially same average level and dispersion of measured efficiency, and both ranked the individual banks in almost the same order. Following this result the researcher preferred to use the translog functional form. The Trans log cost function is specified as follows.

$$\ln C_{it} = \beta_o + \beta_1 \ln X_{1it} + \beta_2 \ln X_{2it} + \beta_3 \ln X_{3it} + \beta_4 Y_{1it} + \beta_5 Y_{2it} + (V_{it} + U_{it});$$

$$i = 1,2\ldots14 \text{ and } t = 1,2\ldots6 \text{—(5)}$$

Where,

$\ln C_{it}$ = is the natural log of total cost of the i^{th} firm at a time t. As indicated earlier in the previous section, Banks total cost is represented by total interest expense and total non-interest expense of each Bank in each year.

$\ln X_{it}$ = is the natural log of price of inputs of the i^{th} firm at time t where by

$\ln X_{1it}$ = is price of input X_1 of the i^{th} bank at a time t. In turn, X_{1it} is the price of deposit (The ratio between interest expense and interest bearing deposit) of each bank in each year).

$\ln X_{2it}$ = is input W_2 of the i^{th} bank at a time t. Similarly, X_{2it} is the price input labour, wage, of each bank in each year.

$\ln X_{3it}$= is input X_3 of the i^{th} bank at a time t. In turn, X_{3it} is the price of input capital, Depreciation cost, of each bank in each year.

Y_{it} = is the natural log of quantities of outputs of the i^{th} firm at a time t. where by

Y_{1it}= is the quantities of output Y_1 of the i^{th} bank at a time t. In turn, Y_{1it} is the quantities of output, total loan of each bank in each year.

Y_{2it}= is the quantities of output Y_2 of the i^{th} bank at a time t. Similarly, Y_{2it} is the quantities of output, other investment of each bank in each year. i is running from i_1 to i_{13} -representing each of the 13 banks under consideration and t are running from t_1 to t_{10} representing each year.

β_s = is a vector of unknown parameters to be estimated;

The error term further decomposed into

$\varepsilon_{it} = V_{it} + U_{it}$

V_{it} represent the random error term, which follows a normal symmetric distribution around the border, N (0, σ^2v) incorporates measurement error and luck that may results in high or low costs for banks. They assumed to be independently and identically distributed normal random variables with zero means and variances σ^2v.

U_{it}= is non-negative random variables ($U_i \geq 0$), which is assumed to account for technical inefficiency in cost. If the firm produce at their stochastic cost frontier it means U_{it} =0 which in turn means that the firm operates at full level of efficiency. If the firm operates below the frontier then U_{it} takes the value greater than zero but less than one. U_{it} depicts factor(s) that cause cost to decrease below the best practice level. Hence,

$U_{it}=U_{it}\exp(-\dot{\eta}(t - T))$.

μ is a parameter to be estimated

γ and $\dot{\eta}$ = are parameter to be estimated, where $\dot{\eta}$ and γ indicating time and interbank variation of efficiencies respectively.

Moreover, the parameterization of Battes and Corra (1977) is employed, who replaced σ^2v and σ^2u with $\sigma^2 = (\sigma^2u + \sigma^2v)$, $\lambda=\sigma u/\sigma v$ and $\gamma = \sigma^2u/(\sigma^2u + \sigma^2v)$. As emphasized by (Coelli et al. 1998) the γ -parameterisation has an advantage in seeking to obtain the maximum likelihood estimates because the parameter space for γ can be searched for a suitable starting value for the iterative maximization algorithm involved. In particular, a value of γ of zero indicates that the deviations from the frontier are due entirely to noise, while a value of one would indicate that all deviations are due to inefficiency. If $\lambda \to +\infty$, we get the deterministic frontier. If $\lambda \to 0$, it turns out that there is no inefficiency in disturbances, every firm sets on the frontier, and the model can be estimated by means of OLS methods. As we know, a deterministic frontier involves that any shift from the frontier (both from random noise or misspecification of the functional form or data errors) is treated as inefficiency. Thus, the error term contains cost volatility (albeit temporary) of the

production units: the best-practice frontier is then stochastic and depends on various random occurrences, not all under the direct control of managers.

To decrease the number of parameters and consequently, to win in terms of degrees of freedom, the following limitations must be imposed:

$\alpha_{1j} = \alpha_{j1}$ and $\beta_{k1} = \beta_{1k}$…… (Symmetry constraints)

The above (Battese and Coelli, 1995) models, presented in Equation (4), (5) and (6), can be estimated using the computer program, FRONTIER version 4.1, written by (Coelli, 1994). FRONTIER 4.1 is a single purpose package specifically designed for the estimation of stochastic cost frontiers and has the advantage of specifying distributional assumptions for the estimation of the inefficiency terms. In addition, FRONTIER can accommodate a wider range of assumptions about the error distribution term such as half-normal and truncated normal distributions. Thus, this study used the software FRONTIER 4.1, setting $\dot{\eta}=0$(time invariance), to obtain the maximum likelihood estimates for parameters of the stochastic frontier model and efficiency level.

The Tobit Model

In situations in which the value of the dependent variable, such as efficiency scores, is constrained between one and zero, the Tobit regression model is believed to generate consistent estimates of regression coefficients than the ordinary least square (OLS) models. Thus, following the footprints of those who tried to assess the factors that affect the efficiency of banks such as Delis and Papanikolaou (2009), the present study used the Tobit regression model to look into the major variables that affect the cost efficiency of the commercial banks in Ethiopia. The study considered Size of the bank (total asset), capital adequacy ratio, intermediation ratio, return on asset and equity, liquidity, equity multiplier, branch network and age of the bank as factors that may influence the efficiency of the commercial banks.

The equation for the determinant of cost efficiency variables can be specified as follows:

$$Eff_{it} = \theta_0 + \theta_1 Z_{1it} + \theta_2 Z_{2it} + \theta_3 Z_{3it} + \theta_4 Z_{4it} + \theta_5 Z_{5it} + \theta_6 Z_{6it} + \theta_7 Z_{7it} + \theta_8 Z_{8it} + \theta_9 Z_{9it} + \varepsilon_i \ldots\ldots\ldots\ldots 5$$

Where: Eff_{it} are the cost efficiency scores estimated using DEA, the subscripts i and t denote bank i at time t, is the constant, θ_i are the coefficients, ε_i is the error term, and represent the explanatory variables. Here negative and positive signs of the parameters reveal that they can increase or decrease bank`s cost efficiency respectively.

Results and Discussion

Descriptive Analysis

Table 1 summarizes averages, standard deviations, as well as the minimum and maximum values of basic and bank specific variables of commercial banks held within the sample. These descriptive values of the inputs, outputs, the dependent variables, and the environmental variables show differences and variations between the various banks.

Table 1

Descriptive statistics of the inputs and outputs variable

Variable name	Mean	Standard deviation	Min	Max
Total Cost (in million Birr)	637.00	59.00	24.80	2320.00
Input Prices				
Price of labor (in 1000 birr)	89179.81	3832.54	39090.47	184239.5
Price of capital (W2)	2.73	2.41	0.064	202.70
Price of fund (W_3)	0.023	0.00068	0.004	0.04
Outputs(in millions' Birr)				
Loans & Advance (in million Birr)	4920.00	482.00	60.70	22600.00
Other investment (in million Birr)	1930.00	195.00	9.714	8280.00

Source: Author's computation based on NBE data and annual report of individual banks

Total cost of commercial banks, were include interest expense, operating expense, personal expense, administrative expense and general expense. According to Table 1, mean of total cost was 637 billion ETB annually. The standard deviation of total cost was 59 billion ETB that indicated the data points were spread out over a wider range of values. Price of labor is the ratio of personal expense to number of employees. Mean of price of labor was 89,179,810 ETB annually. This indicated that commercial banks were paid 89,179,810 ETB annually on average. The standard deviation of price of labor was 3,832,539 annually. Price of capital is the ratio of operating expense to fixed asset. Mean of price of capital was 2.73. Price of fund is the ratio of

interest expense to total deposit. Mean of price of fund was 0.028691 annually. The mean of loan and advance was 4920 billion ETB annually. This indicated that Ethiopian commercial banks were provided loan annually on average 4920 billion ETB. The standard deviation was 482 billion ETB that indicated the data points were spread out over a wider range of values. The mean of other investment was 1930 billion ETB. This indicated that Ethiopian commercial banks were earned on average 1930 billion ETB annually from other investment.

Table 2

Mean of capital Adequacy ratio, liquidity, intermediation ratio, return on asset and bank size

Description	Capital adequacy ratio	Liquidity	Intermediation Ratio	Return on Asset	Return on Equity	Bank Size
DB	11%	32.22	57.67	4.79	28.77	24,500,000,000
AIB	7%	27.61	65.19	3.24	25.08	23,700,000,000
BoA	12%	31.08	57.95	2.76	23.38	14,200,000,000
WB	18%	31.19	63.54	3.13	17.55	135,000,000,000
UB	12%	22.12	62.01	1.20	9.93	14,000,000,000
LIB	16%	40.41	61.63	3.23	20.16	5,660,000,000
CBO	12%	39.51	65.05	2.95	25.38	9,560,000,000
NIB	17%	28.58	66.05	3.22	19.03	13,000,000,000
ZB	14%	42.80	54.71	3.96	27.45	5,250,000,000
OIB	12%	33.27	54.20	2.35	19.05	8,330,000,000
BuIB	16%	33.00	67.00	2.94	17.57	4,610,000,000
BrIB	18%	42.95	62.36	3.48	20.35	4,690,000,000
AB	17%	34.61	60.52	2.80	16.59	4,300,000,000
AdIB	17%	52.74	66.77	1.89	7.60	1,680,000,000

Source: Author's computation based on NBE data and annual report of individual banks

Capital adequacy ratio is the ratio of total capital to total asset. According to table 2, Addis International Bank is at the top position with an average of 27.42% followed by Wegagen Bank with an average ratio of 17.81%. Birhan International bank is the third with an average of 17.65%. While, Awash International bank is achieving the lowest position on an average of total capital to total asset ratio of 6.85%.

Liquidity is the ratio of liquid asset to total deposit. Liquidity ratio measures the bank's ability to meet its current obligation. Regarding the above table, Addis International bank is at first place with highest mean of 52.74, which was followed by Birhan International bank with mean of 42.95, and Zemen bank was the third with mean of 42.79, while United bank is at last place with least mean of 22.12 followed by Awash Bank with mean of 27.6.

Intermediation Ratio is the ratio of total loan to total deposit. According to the above table, Bunna International bank ranked first with mean of 67 followed by Addis International bank with mean of 66.77 and the third is Nib International Bank with mean of 66.05, while Oromia International bank ranked to the least place with the mean of 54.20. This means that Oromia International bank is depend on collecting deposit than providing loan.

Return on Asset is the ratio of gross profit to total asset. It is indicator of how profitable is relative to its total asset. According to the above table, Dashen bank ranked first with mean of 4.79 followed by Zemen bank with mean of 3.96 and the third is Berhan International Bank with mean of 3.48, while United bank ranked to the least place with the mean of 3.24.

Return on equity is the ratio of gross profit to equity. It is profitability ratio that measures the ability of a firm to generate profit from its shareholder investment in the company. According to the above table, Dashen bank ranked first with mean of 28.76 followed by Zemen bank with mean of 27.45 and the third is Cooperative bank of Oromia with mean of 25.38, while Addis International bank ranked to the least place with the mean of 7.6.

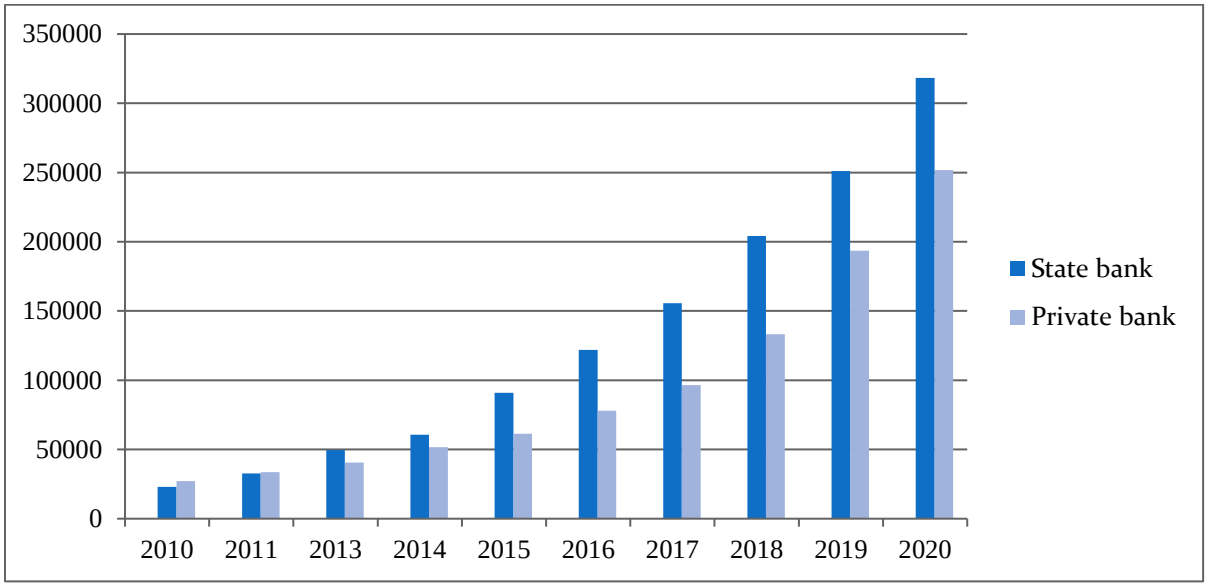
The bank size is measuring the value of total asset of the bank. According to the above table, Dashen bank ranked first with mean of 24,500,000,000 Birr followed by Awash bank with mean of 23,700,000,000 Birr and the third is Bank of Abyssinia with mean of 14,200,000,000 Birr, while Addis International bank ranked to the least place with the mean of 1,680,000,000 Birr and followed by Abay bank with mean of 4,300,000,000 Birr.

Comparison of State and Private Commercial Bank

The state and private commercial banks are increasing their outreach and growing in terms of their assets, deposits and loans. Figures 1, 2 and 3 show the average deposits, loans, and assets of state-owned and private commercial banks over the period 2010-2020. As the figures indicate, the share of private commercial banks in deposits, assets and loans has increased over the study period. The total deposits of state-owned commercial banks ranges between Birr 22,863 million in 2010 and Birr 318,243 million in 2020. The private commercial banks total deposits range between Birr 27,208 million in 2010 and Birr 251,859, million in 2020. The total loan and advance of state-owned commercial banks ranges between Birr 23,573 million in 2010 and Birr 197,313 million in 2020. The private commercial banks total loan and advance range between Birr 20,559 million in 2010 and Birr 235,634 million in 2020. The total asset of state-owned commercial banks ranges between Birr 23,573 million in 2010 and Birr 197,313 million in 2020. The private commercial banks total asset range between Birr 810 million in 2010 and Birr 15,968 million in 2020. In the same fashion the shares of the state-owned commercial banks in terms of total assets and total loans and advances are increasing.

Figure 1

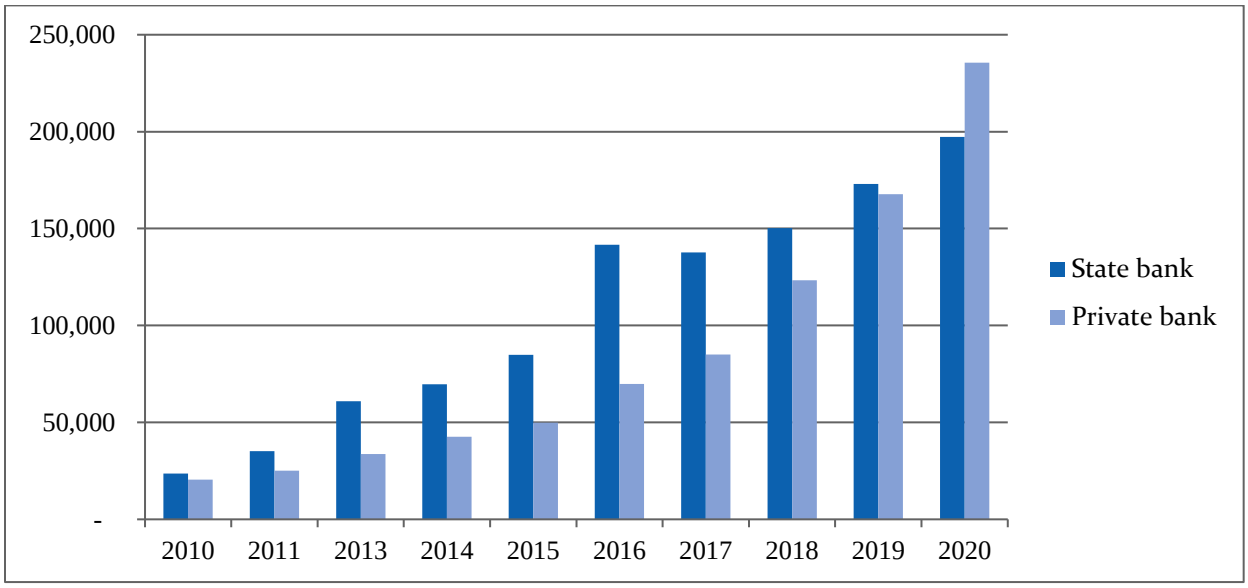
Total deposit state and private commercial banks



Source: Author's computation based on NBE data

Figure 2

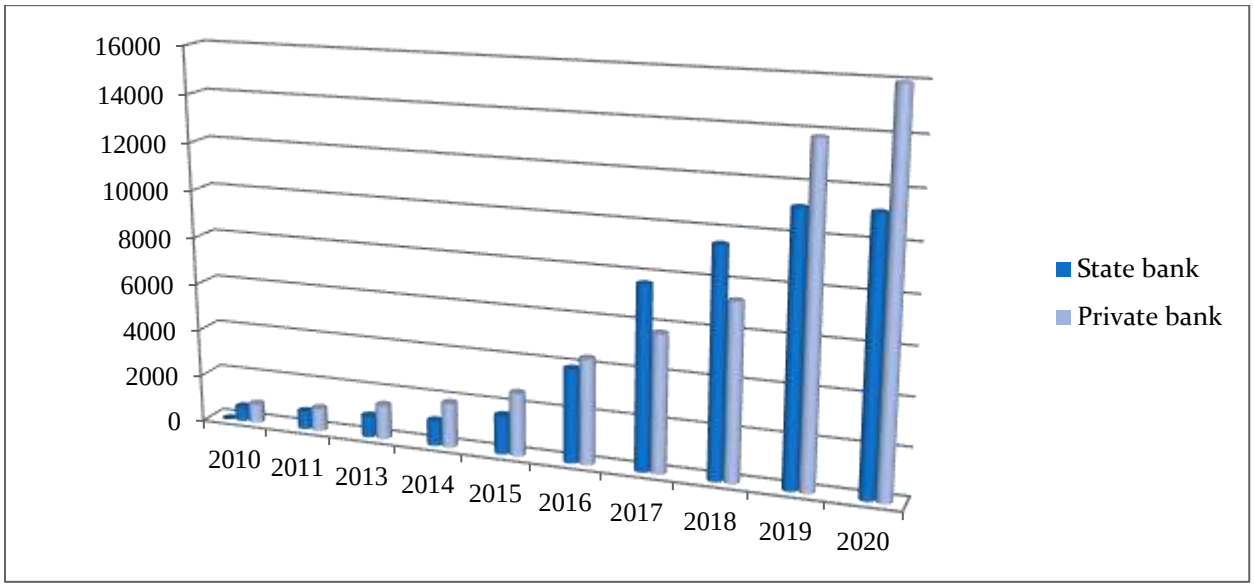
Total loans of State and Private commercial banks



Source: Author's computation based on NBE data

Figure 3

Total assets of State and Private commercial banks



Source: Author's computation based on NBE data

Cost frontier Estimates

Since early, Aigner et al. (1977) first estimated the unknown parameters of the stochastic frontier model using the method of maximum likelihood method followed also widely in later decades by Greene (2002) and Coelli (1995), among others. A maximum likelihood estimator that takes into consideration this information should therefore give more efficient estimates, at least asymptotically. Maximum likelihood estimation is a popular statistical method used for fitting a mathematical model to real world data. Gamma distribution is one of the distributions, which provides a maximum likelihood estimator with all of the usual desirable properties and is characterized by a high degree of flexibility (Mastromarco, 2008). The main advantage in using panel data is that it allows relaxation of the strong assumptions required in the estimation of a cross-section, namely assumptions on the independence of the components of the error term and the regressors, and distributional assumptions on the inefficiency and statistical noise. The advantage of panel data, as noted by Cornwell and Schmidt (1996), "repeated observation of the same firm makes it possible to estimate its level of efficiency more precisely."

The researcher estimated the stochastic frontier models, as it was discussed in the research methodology part, using FRONTIER (version 4.1) computer software. The researcher estimated by using (Berger and Mester, 1997). In this section, the researcher discusses the result of those models. Before going to the discussion of the estimated result, the researcher has to check (judge) the suitability of using the stochastic frontier model. Since, the analysis of stochastic frontier model can only be used when the U_{it}'s (the cost inefficiency effect) are stochastic and have the required distribution properties.

Hypothesis Testing

Hypotheses stated in the model specification part and validity of the model which is used for analysis has to be tested before estimating the parameters of the model. One attractive feature of SPF method is that it is possible to test various hypotheses using maximum likelihood ratio test, which were not possible in non-parametric models (Thiam et.al, 2001).

Log likelihood (LR) =-2[L (H0)-L (H1)], where L (H1) and L (H0) are the values of the log likelihood functions under the alternative and null hypothesis, respectively (Greene, 1980). The ML estimates of hypothesis tests are found in Appendix part.

Therefore, before discussing about parameter estimates of cost frontier function and the inefficiency effects, it is advisable to run the several hypotheses tests in order to choose an appropriate model for further analysis and interpretation.

Table 3

Generalized likelihood-ratio test of hypotheses for parameters of SFA

Null hypothesis	**Calculated LR**	**Critical LR**	**Decision**
Ho: $\gamma = 0$	83.677	6.635	Reject Ho
Ho: $\theta_0=\theta_1=\theta_2 \ldots =\theta_9 = 0$	106.94	6.635	Reject Ho

Source: Author's computation

The first hypothesis testing is the parameters that can be used to judge the suitability of using the stochastic frontier model. Under the formulation used, testing for the presence of the bank specific inefficiency and hence the necessity of using the frontier model, translate into testing the hypothesis H_O: γ=0.The test is done using the log likelihood ratio (LR) test of FRONTIER version 4.1, estimation. The test statistics has mixed chi-square distribution and the critical value for a given level of significance is lower than that reported in the usual chi-square tables (Kumbhakar and Sarkar, 2004).

The generalized likelihood ratio test requires the estimation of the model under both the null and alternative hypothesis. Under the null hypothesis, H_O: γ=0, the model is equivalent to the traditional average response function, without the X-inefficiency, U_{it}. as:

$$LR= -2\{ \ln[L (H_O)] - \ln [L (H_1)]\}$$

Where $L(H_O)$ and $L(H_1)$ are the value of likelihood function under the null hypothesis(restricted model) and alternatives hypothesis(unrestricted model), respectively. As can be seen from Table 3.4, the log likelihood function for the full stochastic frontier is calculated to be 38.285 and the log

likelihood function under alternative hypothesis the cost function is -34.94 (the natural log of -35.8172033 would be -3.5536). -3.5536 were much less than that for the full frontier model. This implies that the Generalized LR-ratio statistic for testing the absence of the X-inefficiency effects from the frontier is 83.677. This value is significant because it exceeds 6.635, which is the critical value obtained from (χC2) at 1 percent level of significance with degrees of freedom of 1. Hence, the analysis overwhelmingly rejects the null hypothesis of no X-inefficiency effects in private commercial banks in Ethiopia. Thus, the standard average response function is not adequate for analyzing the cost behavior of banks and a frontier model is required. This implies that the stochastic frontier specification fits the data better than a deterministic frontier. Thus, the model implies that the cost efficiency of the bank is better analyzed within a stochastic frontier framework.

The estimated value of gamma is equal to 0.9999, which is statistically significant at 1% level of significance(t-cal=1695.9). The estimated value of gamma signifies that 99.99% of the variation in output is due to the variation in cost inefficiency among the banks while the remaining 0.001% of output variation is due to variation in random shocks. This indicates that there is wider room to increase cost efficiency of private commercial banks in Ethiopia through identification of principal factors affecting cost efficiency.

The second hypothesis is that the explanatory variables in cost inefficiency effect model are simultaneously equal to zero, Ho: $\theta_0 = \theta_1 = \theta_2 \ldots\ldots = \theta_9 = 0$. To test this hypothesis log- likelihood ratio is calculated using the value of the log likelihood function under the stochastic frontier model (a model without explanatory variables of inefficiency effect model, H0) and the full frontier model (a model with all explanatory variables of inefficiency effect model, H1). The calculated value of LR equals to 106.94 while the critical likelihood ratio (χC2) of upper 1 percent level of significance at 1 degree of freedom equals to 6.635. Since the calculated likelihood ratio, LR value is greater than the critical value of LR, χC2 at 9 degree of freedom with upper 1 % level of significance, the null hypothesis that determinant variables in the inefficiency effect model are simultaneously equal to zero is rejected at 1% level of significance. Therefore, the explanatory variables associated with inefficiency effect model are jointly different from zero. Hence, these variables jointly explain inefficiency differences among the banks'

First Stage Analysis

In this study, to measure private commercial banks cost efficiency and analyze its principal determinants, the stochastic frontier approach has been used. For the stochastic frontier cost function, three input variables (price of labor, price of capital and price of deposit) and two output variables (loan and advances and other earning) are used. The selection of cost inefficiency effects is based on the literature, data availability, and prior knowledge of firm's efficiency.

Table 4

Maximum likelihood Estimate of the Stochastic Frontier Analysis

Variable	Parameter	Coefficient	t-ratio
Constant	β_0	-0.21248837**	-0.54563278
Price of Labor	β_1	0.18812547***	6.621492
Price of Capital	β_2	-0.0028769674	-0.14457268
Price of deposit	β_3	0.64410738**	12.975068
Loan and Advance	β_4	0.91756412***	44.209516
Other Investment	β_5	-0.25531752	-0.1507227
Sigma square(σ^2)		0.39289492***	6.6793936
Gamma(γ)		0.999945***	1695.9172
Log likelihood function(LL)		38.284887	
Lambda (λ)		99.2726	

Source: own computation

NB: ***= Significant at 1 %; **= Significant at 5 %; *= Significant at 10 %

On table above, the Parameter γ (gamma) indicates the relevance of stochastic frontier model specification. It measures the variation between observed cost and the best practice on the frontier. If the value of gamma close to zero, all banks in the sample produces their output with the available inputs in the same way i.e. there is no inefficiency operation practices among the banks. On the other hand, if the value is different from zero there is an inefficient operation among the banks. So that, the acceptance of the null hypothesis γ= 0, means that μi=0 and that the x-inefficiency (μi) must be removed from the model. Nevertheless, as shown in table 4.4, $\gamma \neq 0$ this means, there is difference in operational practice among banks.

According to above table, the estimated variance of the one-sided error term is found to be $\sigma^2 u$ = 0.3928 and that of the statistical noise $\sigma^2 v$ = 0.0004. The ratio parameter estimated gamma (γ) is statically significant and positive indicating that the cost inefficiency effects that impact the

operation of the banks under consideration is significant. The hypothesis on two sided noise component (V_{it}) (γ=0) is rejected and this result is confirmed by the significance of the coefficient of the parameter γ. (i. e, γ=0.999945).

This estimate (γ=0.999945) is high, meaning that much of variation in the composite error term is due to the inefficiency component. These findings support the parameterization of the variance of the noise component as the source of noise seem to vary with firm size. That means, efficiency is bank variant (differs from Bank to Bank). The degree of asymmetry can be represented by the following parameter $\lambda=\sigma_u/\sigma_v$. The larger λ is, the more pronounced the asymmetry will be. On the other hand, if λ is equal to zero, then the symmetric error component dominates the one-side error component in the determination of ε_i (Mastromarco, 2008).

Again, the ratios of the standard error of *u* to that of *v*, λ (99.2726) exceeded one in value and are statistically different from zero at the 1 % level of significance. The values of λ and the fact that it is significantly different from zero implies the good fit and the correctness of the specified normal distributional assumption of the one-sided error term. As Aigner et al. (1977) mentioned it, if $\lambda^2 \rightarrow 0$, it turns out that there is no inefficiency in disturbances, every firm lays on the frontier, and the model can be estimated by means of OLS methods and if $\lambda^2 \rightarrow \infty$, it turns out that there is inefficiency. From the above table, the value of λ^2 is 9,855. Therefore, it means that inefficiency error is dominated by random error.

All slope coefficient of the stochastic frontier indicated in the table 4, since the value of both the dependent and the regressors are converted into logarithmic forms, their first coefficients can be directly interpreted as cost elasticity's. Accordingly, the estimate cost of the cost elasticity with respect to price of labor ($\beta_{1=}$ 0.18812547), price of deposit ($\beta_{3=}$ 0.64410738), and loan and advance ($\beta_{4=}$ 0.91756412) are positive and statistically significant. This mean that the banks total cost is highly responsive to the banks' loan and advanced (91.75%) and price of deposit (64.4%) than by price of labor (19%). In another word, a small provide loan for the customers may bring significant change on total cost than the cost incurred for personnel expense. While the estimate cost of the cost elasticity with respect to price of capital ($\beta_{4=}$ -0.0028769674) and other investment ($\beta_{4=}$ -0.25531752) are negative and statistically significant.

The estimate cost of the cost elasticity with respect to price of labor ($\beta_{1=}$ 0.18812547) positive and statistically significant at 1% level of significance. This indicate that a one percentage change in price of labor 19 percent change in total cost of the banks. In another word, an increment shown on labor cost may bring a percentage increment in total cost. It indicates that the low payment level of wages and salaries paid for the employees compared to total number of employees. This means that banks those reduce personal expense can reduce total cost. The estimate cost of the cost elasticity with respect to price of deposit ($\beta_{3=}$ 0.64410738) positive and statistically significant at 5% level of significance. The positive sign of price of deposit indicate that since the increase in interest payment raises the costs of banks and consequently their levels of inefficiency. This indicate that a one percentage change in price of deposit 64.44 percent change in total cost of the banks. In other words, banks increased the amount of deposit than increase amount of loan. Private commercial banks were focus on the collect deposit than loan provide for customers. This was highly affected their cost efficiency. This means that banks those reduce interest expense can reduce total cost.

The estimate cost of the cost elasticity with respect to loan and advances ($\beta_{4=}$ 0.91756412) positive and significant at 1% level of significance. This indicates that a one percentage change in loan and advances 91.75 percent change in total cost of the banks. The positive sign of loans and advance indicates that the collected funds from customers by providing less interest payment and lend afterward by collecting high interest payment that serve to decrease the costs of financial intermediation and consequently increases the efficiency level of banks. This is the most highly affect cost efficiency than others input output. This means that, banks those increase amounts of loan can reduce total cost.

Cost efficiency level of Ethiopian commercial banks

Cost efficiency ranges from zero to one, and equals one for a best-practice firm (Kumbhakar and Sarkar, 2004).

Table 5

Cost efficiency level of Ethiopian commercial banks

	Years										
	01	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**Mean**
AIB	0.88	0.90	0.93	0.93	0.87	0.89	0.88	0.93	0.93	0.96	**0.91**
BoA	0.95	0.90	0.91	0.87	0.83	0.71	0.73	0.89	0.86	0.89	**0.85**
BrIB	0.86	0.93	0.93	0.97	0.78	0.81	0.91	0.83	0.71	0.75	**0.85**
BUIB	0.76	0.92	0.96	0.95	0.80	0.90	0.93	0.94	0.91	0.92	**0.90**
CBE	0.92	0.79	0.97	0.91	0.91	0.96	0.84	0.55	0.38	0.31	**0.75**
CBO	0.74	0.44	0.77	0.72	0.87	0.97	0.80	0.74	0.74	0.71	**0.75**
DB	0.89	0.89	0.92	0.86	0.80	0.75	0.67	0.74	0.74	0.89	**0.82**
LIB	0.92	0.81	0.90	0.94	0.80	0.74	0.81	0.89	0.90	0.90	**0.86**
NIB	0.92	0.84	0.93	0.97	0.97	0.91	0.83	0.91	0.88	0.94	**0.91**
OIB	0.53	0.63	0.58	0.57	0.66	0.84	0.59	0.60	0.77	0.87	**0.66**
UB	0.93	0.94	0.93	0.77	0.42	0.34	0.43	0.56	0.90	0.95	**0.72**
WB	0.89	0.74	0.89	0.90	0.55	0.76	0.80	0.83	0.87	0.81	**0.80**
ZB	0.81	0.91	0.94	0.93	0.92	0.92	0.96	0.94	0.92	0.70	**0.90**
Mean	**0.85**	**0.82**	**0.89**	**0.87**	**0.78**	**0.81**	**0.78**	**0.80**	**0.81**	**0.82**	**0.82**

Source: own computation by using FRONTIER 4.1

Table 5 presents the cost efficiency of state and private commercial banks over the period 2010-2020. The cost efficiency of the state-owned commercial banks over the period is 0.75. This indicates that a state-owned commercial bank on average could have incurred only 75 percent of what it actually outlaid to produce the same level of output over the study period. On the other hand, the cost efficiency of the private commercial banks over the study period is found to be 83. This implies that, an average private commercial bank could have incurred only 83 percent of the cost it actually incurred to yield the same level of output over the study period. Stated in other words, the study indicates that an average state-owned commercial bank could have cut its cost, without making any reduction in its output level, by 25 percent over the study period while an average private commercial bank could have reduced its cost by 17 percent over the same period. Moreover, the study shows that the average cost of efficiency of the private banks (0.83 is a bit

higher than the aggregate cost efficiency of state-owned commercial bank (0.75). This indicates that, private commercial banks are more cost efficient than state owned commercial banks.

Ethiopian commercial banks scored highest cost efficiency level during 2012 over the study period. While, during 2014 and 2016 their cost efficiency level is low over the study period. Nib international bank and Awash Bank are the most cost-efficient bank from the group, with a score of 0.91 and followed by Buna International bank and Zemen bank with score of 0.90. This implies, Awash Bank and Nib international bank have incurred only 91 percent of the cost it actually incurred to yield the same level of output over the study period. This implies that, Nib international bank and Awash Banks had the capacity to produce their outputs with less of input costs.

Nib international bank is the most cost efficient due to three reasons: 1) Well capitalization and better diversification of the bank asset portfolio. This implies that, the bank had reduced the risk of collectability of loans. As a result, the bank reduced the amount of doubtful loan expenses during the sample period. 2) Higher volume of healthy loans this is due to good credit policy of the bank, 3) Lower numbers of branch, most of them were opened based on a good feasibility study.

Awash bank is the second cost efficient over the study period. The main source of higher cost efficiency for Awash bank is due to skillful and competent managers of the bank and good asset portfolio management practices that helped to minimize the cost x-inefficiency of the bank.

Oromia International Bank is the least cost-efficient bank from the group, with a score of 0.66 and followed by United bank with score of 0.72. The main sources of the lowest cost efficiency score of Oromia International Bank is the following. Unstable internal management and misalignment practice of the bank management in coordinating the company resource and capabilities with the corporate goals; Lack of good credit policy and assets portfolio management practice of the bank lead to higher amount of bad debit expenses that reduced the bank's profit.

Generally, Ethiopian commercial banks cost efficiency level is range between 0.66 and 0.91. This study found that, Ethiopian commercial banks cost efficiency is fluctuated over the study period. The study shows that, the aggregate average cost of efficiency of Ethiopian commercial banks is

0.82. This implies that, the aggregate an average Ethiopian commercial bank could have incurred only 82 percent of the cost it actually incurred to yield the same level of output over the study period. The study indicates that an average Ethiopian commercial bank could have cut its cost, without making any reduction in its output level, by 18 percent over the study period. The result of the study is consistent with the finding of Rao and Tekeste (2012) who contend that state owned commercial banks are as cost efficient as private commercial banks. The study indicates that state-owned commercial banks are as cost efficient as private commercial banks in Ethiopia. This could be clarified two ways. First, the state-owned commercial banks have been operating since long time and might have learnt a lot in carrying out banking activities in the most efficient ways. Second, following the liberalization of the country's financial sector in 1994, the state-owned commercial banks are required to perform their activities as business organizations and equally compete with the private commercial banks in mobilizing savings, extending loans and rendering other banking services. This has forced the state-owned banks to make use of resources in the most efficient ways in their effort to remain competitive in the banking market.

Second Stage Analysis

In order to give further insight into variation of cost efficiency scores among individual commercial banks, a second stage analysis is conducted. Under this second stage analysis procedure, the estimated cost efficiency scores computed in stage one analysis, taken as dependent variable and regressed against different factors that influenced and affected the cost efficiency of private commercial banks operating in Ethiopia. An attempt has been made to explore the key factors that influence the cost efficiency of the commercial banks. The Tobit model is considered to be superior to OLS as it considers the censored nature of the efficiency scores (i.e. the dependent variable). The cost efficiency estimates are bounded between 0 and 1. Therefore, this research paper applies the Tobit regression procedure with a left censored bound of 0.31 and right censored bound of one to regress the cost efficiency 0.97 scores against set factors (i.e. bank size, return on asset, return on equity, capital adequacy ratio, intermediation ratio, age of the banks, branch network and real gross domestic product). The result of the Tobit regression analysis is presented in table 6:

The study found three of the explanatory variables to have significant influence on the cost efficiency of the banks. Return on equity is statistically significant and is also positively correlated with cost efficiency. A positive correlation between return on asset and cost efficiency suggests that bank size has a positive impact on cost efficiency of banks. The result of the study is consistent with the findings of Grigorian and Manole (2006) and Chortareas et al. (2011) but not to those of Chronopoulos et al. (2011). According to the literature, there are two potential reasons for this relationship. First, higher equity alleviates agency problems between the management and owners. As owners acquire higher stakes in the bank, their tendency to monitor the management is higher, which leads to higher cost discipline and thus higher cost efficiency (Mester, 1996, and Eisenbeis et al., 1999).

Financial intermediation ratio is statistically significant and is also positively correlated with cost efficiency. Financial intermediation ratio shows the relationship between financial development and capital formation. The more the ratio of intermediation is high, the lower are the banking costs, and the higher will be the efficiency of banks. Banking systems with a higher intermediation ratio (ratio of financial asset to capital formation) have significantly lower costs. This may reflect the developments in the legal and regulatory framework, which support both the financial intermediation process and lower costs to banks. These may include the development of effective secured transactions laws and bankruptcy procedures, which are necessary to support lending to customers (Lyocsa and Pancurova, 2013).

Branch network or number of branches is also found to have significant and negative effect bank's cost efficiency. The negative correlation coefficient sign of branch network with cost efficiency is due to branch expansion that causes banks to incur more cost for rent, administration and other contingent costs and management attention may divert from cost minimization to focus on to other routine administration activities. This increases cost inefficiency because of the direct relationship of cost and bank's cost efficiency.

Moreover, bank size, return on asset, capital adequacy ratio, and real gross domestic product are found to be statistically insignificant and positively associated with cost efficiency. While, age of the bank is statistically insignificant and negatively associated with bank's cost efficiency.

Table 6

Tobit model estimation result

Description	Coefficient	Std. Err	t	P > |t|
Bank Size	0.0303	0.0393	0.77	0.443
Return on Asset	0.0133	0.0166	0.80	0.427
Return on Equity	0.0058	0.0018	3.19	0.002
Capital Adequacy Ratio	0.7204	0.5056	1.42	0.157
Intermediation Ratio	0.1962	0.0823	2.38	0.019
Branch Network	-0.00038	0.00012	-3.27	0.001
Age	-0.00013	0.0026	-0.05	0.962
RGDP	0.06737	0.1016	0.66	0.509
Constant	-0.6305	0.6081	-1.05	0.296
Prob > chi^2	0.0000			
R^2	-0.519			
LR chi^2 (8)	56.15			
Left Censored	CE < =0.31			
Right Censored	CE < = 0.97			

Source: Own computation by using STATA

Conclusion and Policy Implication

The main aim of this study was to examine the determinant of cost efficiency of 13 commercial banks in Ethiopia during the period of 2010-2020. The study used the parametric approach, stochastic frontier analysis, in measuring the cost efficiency and its determinant of the private commercial banks. Hence, results show that except price of capital all input variables have significant and positive effect on cost efficiency in the study period. From output variables, loan and advance have significant and positive effect on cost efficiency in the study period; while other earning variable was insignificant and negative effect on the cost efficiency in the study period.

Loan and advance have the highest elasticity, then price of deposit and followed by price of labor with value of 0.92, 0.644, and 0.19, respectively. This is an indicative of the small provide loan for the customers may bring significant change on total cost than the cost incurred for personnel expense. Those banks had provided high loan for customer were high for cost efficiency than that of provided less loan for customer. This means that, when banks reduce amount of loan provide, interest expense become increased. This implies that enhanced the amount loan could improve the cost efficiency of commercial banks. Measuring the efficiency of financial institutions has received considerable attention in recent time (Janjua & Malik, 2011). Such studies are significant for

policymakers for the accurate assessment of the effects of their decisions on the institutions they supervise.

The cost efficiency of the state-owned commercial banks over the period 2010-2020 is 0.75. On the other hand, the cost efficiency of the private commercial banks over the study period is found to be 0.83. Moreover, the study shows that the average cost of efficiency of the private banks (0.83 is a bit higher than the aggregate cost efficiency of state-owned commercial bank (0.75). This indicates that, private commercial banks are more cost efficient than state owned commercial banks. Ethiopian commercial banks are scored highest cost efficiency level during 2012 over the study period. While, during 2014 and 2016 their cost efficiency level is low over the study period. Nib international bank and Awash Bank are the most cost-efficient bank from the group, with a score of 0.91 and followed by Buna International bank and Zemen bank with score of 0.90. Oromia International Bank is the least cost-efficient bank from the group, with a score of 0.66 and followed by United bank with score of 0.72. Return on equity is statistically significant and positively correlated with cost efficiency. Financial intermediation ratio is statistically significant and positively correlated with cost efficiency. Branch network or number of branches is also found to have significant and negative effect bank's cost efficiency.

Moreover, bank size, return on asset, capital adequacy ratio, and real gross domestic product are found to be statistically insignificant and positively associated with cost efficiency. While, age of the bank is statistically insignificant and negatively associated with bank's cost efficiency.

In order to hold up risky surprises and maintaining financial stability, it is vital to identify the determinants that mostly influence the overall cost efficiency of private commercial banks operating in Ethiopia. Therefore, based on the findings of the study the following possible recommendations were forwarded.

Firstly, commercial banks in Ethiopia should focus to work hard to collect more deposits by design different strategies like convenience of location and quality of customer services and increase the amount of loan provide for customers. Commercial banks shall be open account for Ethiopian citizen those living outside of the country.

Secondly, commercial banks should minimize the use of input resources while maintaining the same level of output. By improved handling of operating expenses, general expense, personal expense, interest expense and by boosting loan providing, the less efficient banks can successfully endorse resource utilization efficiency.

Thirdly, this study highlights the economics of encouraging increased cost efficiency in the banking sector by specifically focusing on bank's specific factors that could possibly affect the cost efficiency of the banks. Return on equity, intermediation ratio, and branch network are significant key internal drivers of cost efficiency of private commercials banks in Ethiopia. Therefore, commercial banks in Ethiopia should focus to improve return on equity and intermediation ratio. Commercial banks should open its branch depend on feasibility study.

Fourthly, as many literatures supports financial development in Ethiopia is still in its early stages even by the standards of other low-income countries and many other metrics such as the total number of banks, banks contribution to GDP, bank accounts per person, branches per person, and bank credit per person are lower in Ethiopia compared to other African countries. Thus, Ethiopian commercial banks should focus to reach this unmet demand of finance by adjusting their strategy with the government regulation.

Finally, the study sought to investigate the factors that influence cost efficiency of commercial banks in Ethiopia. However, the variables used in the statistical analysis did not include all factors that can affect cost efficiency of private commercial banks operating in Ethiopia. Thus, future research could incorporate other new factors such as, inflation rate, government regulation and broad money supply and focus on different aspects of emerging banking systems such as international comparisons.

References

Aigner, D., Lovell, C. K., & Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of econometrics*, *6*(1), 21-37.Ally Z. and G. Patel. (2014). Evaluating Efficiency of Commercial Banks in Tanzania and identifying efficiency drivers. Journal of Business and Management.

Ally, Z., & Patel, G. N. (2014). Evaluating Efficiency of Commercial Banks in Tanzania and identifying efficiency drivers. *IOSR Journal of Business and Management*, *16*(7), 50-64.

Almanidis, J. Q. (2014). Stochastic Frontier Models with Bounded Inefficiency. Econometric Methods and Applications, 47-81.

Battese and Coelli. (1995). A model for technical inefficiency effects in a stochastic frontier production function for panel data. Empirical Economics, 20, 325-332.

Battese and Corra. (1977). Estimation of a production frontier model: With application to the pastoral zone of Eastern Australia. Austrian Journal of Agriculture Economics, 21(3), 169-179.

Berger and Mester. (1997). Inside the Black Box: What Explains Differences in the Efficiencies of Financial Institutions? Journal of Banking and Finance, 21(7), 895-947.

Berger and Mester. (2003). Explaining the dramatic changes in performance of US banks: technological change, deregulation, and dynamic changes in competition. Journal of Financial Intermediation, 12(1).

Chronopoulos, Claudia Girardoneb and John Nankervis. (2011). Are there any cost and profit efficiency gains in financial conglomeration? Evidence from the accession countries. European Journal of Finance.

Coelli. (1994). A Guide to FRONTIER Version 4.1: A Computer Program for Stochastic Frontier Production and Cost Function Estimation.

Coelli. (1995). RECENT DEVELOPMENTS IN FRONTIER MODELLING AND EFFICIENCY MEASUREMENT. Australian Journal of Agricultural Economics.

Coelli. (1998). A multi-stage methodology for the solution of orientated DEA models. Operations Research Letters, 23(3-5), 143-149.

Cooper, J. O., Heron, T. E., & Heward, W. L. (2007). Applied behavior analysis.

Cornwell and Schmidt. (1996). Stochastic Frontier Analysis and Efficiency Estimation.

Das, C. R. (2015). Cost and Revenue Efficiency of State Cooperative Banks in India: Evidence from North-East Using Data Envelopment Analysis. A Journal of National Institute of Bank Management, 35, 32-54.

Delis, M. D., & Papanikolaou, N. I. (2009). Determinants of bank efficiency: evidence from a semi-parametric methodology. *Managerial finance, 35*(3), 260-275.

Eisenbeis, Gary Ferrierand Simon Kwan. (1999). The informativeness of stochastic frontier and programming frontier efficiency scores: Cost efficiency and other measures of bank holding company performance. Working Paper, 99(23).

Emishaw, B. a. (2016). Determinants of Commercial Banks' Cost Efficiency in Ethiopia.

Farrell. (1957). The Measurement of Productive Efficiency.

Ferrier, G. D., & Lovell, C. K. (1990). Measuring cost efficiency in banking: Econometric and linear programming evidence. *Journal of econometrics*, *46*(1-2), 229-245.

Georgios Chortareas, Claudia Girardone and Alexia Ventouri. (2011). Bank Supervision, Regulation, and Efficiency: Evidence from the European Union.

Greenee, W. H. (2002). Econometrics Analysis fifth edition.

Grigorian David & Manole Vlad. (2006). Determinants of Commercial Bank Performance in Transition: An Application of Data Envelopment Analysis. Comparative Economic Studies volume, 48, 497–522.

Humphrey, A. N. (1997). Efficiency of Financial Institutions: International Survey and Directions for Future Research. Financial Institutions Center.

Kablan, S. (2010). Banking Efficiency and Financial Development in Sub-Saharan Africa. International Monetary Fund.

Kariuki, J. (2011). Determinant of cost efficiency level of commercial banks in Kenya.

Kumbhakar and Sarkar. (2004). Deregulation, Ownership, and Efficiency Change in Indian Banking: An Application of Stochastic Frontier Analysis.

Kumbhakar, S. and Lovell, C. (2000). Stochastic Frontier Analysis, Cambridge University Press, Cambridge.

Leibenstein, H. (1966). Allocative efficiency vs." X-efficiency". *The American economic review*, *56*(3), 392-415.

Lelissa, T., & Mohammed, A. (2016). Cost Efficiency of Ethiopian Banks. *Ethiopian Journal of Business and Economics (The)*, *6*(2), 125-158.

Lovell, C. (1995). Econometrics efficiency analysis: A policy-oreinted review. European journal of operational research, 452-461.

Lovell, S. C. (2000). Stochastic Frontier Analysis.

Lyocsa, D. P. (2013). Determinants of Commercial Banks' Efficiency: Evidence from 11 CEE Countries. 152-179.

Malik S.M and Janjua Y. (2011). The Impact of Recent Financial Crisis on Economic Growth and Youth Employment in South Asia. Centre for Research on Economic and Social Transformation.

Mastromarco, C. (2008). Foreign capital and efficiency in developing countries. *Bulletin of Economic Research*, *60*(4), 351-374.

Meeusen and Broeck. (1977). Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error. International Economic Review, 18(2).

Meeusen and van Den Broeck. (n.d.). Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error. International Economic Review, 18(2).

Mester, L. J. (1996). A study of bank efficiency taking into account risk-preferences. Journal of Banking and Finance, 20, 389 - 405.

Mester, L. J. (1996). Measuring efficiency at U.S. banks: accounting for heterogeneity is important. Federal Reserve Bank of Philadelphia Research Working Paper.

Rao, K. R. M., & Lakew, T. B. (2012). Cost Efficiency and Ownership Structure of Commercial Banks in Ethiopia: An application of non-parametric approach. *European Journal of Business and Management*, *4*(10), 36-47.

Raphael, G. (2012). Commercial banks efficiency in Tanzania: A non parametric approach . European Journal of Business and Management.

Raphael, G. (2013). Efficiency of Commercial Banks in East Africa: A Non Parametric Approach. International Journal of Business and Management.

Repkova, I. (2015). Banking Efficiency Determinants in the Czech Banking Sector. Economics and Finance.

Shen and Jones. (2008). Cost Efficiency Analysis in Banking Industries of Ten Asian Countries and Regions. Journal of Chinese Economic and Business Studies.

Stevenson, R. (1980). Likelihood functions for generalized stochastic frontier estimation. Journal of Econometrics, 13(1), 57-66.

Tadele, T. (2016). Determinants of Commercial Banks Efficiency: Evidence from Selected Commercial Banks of Ethiopia. International Journal of Scientific and Research Publications, 6(5), 551-556.

Tekeste and Rama. (2012). Cost Efficiency and Ownership Structure of Commercial Banks in Ethiopia: An application of non-parametric approach. European Journal of Business and Management, 4(10).

Thiam, A., Bravo-Ureta, B. E., & Rivas, T. E. (2001). Technical efficiency in developing country agriculture: a meta-analysis. *Agricultural economics*, *25*(2-3), 235-243.

Varian, H. R. (1992). Micro economics analysis, third edition.

Vitali, Alessio Fontani and Luca. (2014). Vitali, Alessio Fontani and Luca Cost Efficiency of Italian Commercial Banks:A Stochastic Frontier Analysis Universal Journal of Industrial and Business . Management Universal Journal of Industrial and Business Management, 80-91.

Zhao, H., & Kang, S. (2015). Banking Performance Evaluation in China based on non-radial super-efficiency data envelopment analysis. *Procedia economics and finance*, *23*, 197-202.